Impacts of Ocean Currents and Waves on the Wind Stress Drag Coefficient: Relevance to HYCOM

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INTRODUCTION

Surface ocean currents and waves influence the wind stress drag coefficient as shown in the literature.

- Ocean models have current speeds but typically they do not include wave information
- Wind stress formulation for input to HYCOM excludes both current and wave effects.

We would like to answer two questions:

(1) What is the impact of currents and waves on the drag?

(2) Are these effects negligible over the global ocean?

WIND STRESS FORMULATION

- **Wind stress (τ) is parameterized as**

$$\tau = \rho_a \, C_D \, \mathrm{V}^2$$

- **Thus, τ depends on**
  - **(1) density of the air: ρ_a**
  - **(2) drag coefficient: C_D**
  - **(3) squared wind speed V^2**

- **ρ_a and V are well-known but C_D is NOT.**

DRAG COEFFICIENT

- C_D depends on
  - dynamic stability at the air–sea interface, i.e.
    - air–sea temperature difference, and
    - relative humidity at the air–sea interface
- HYCOM includes preceding effects (full stability)

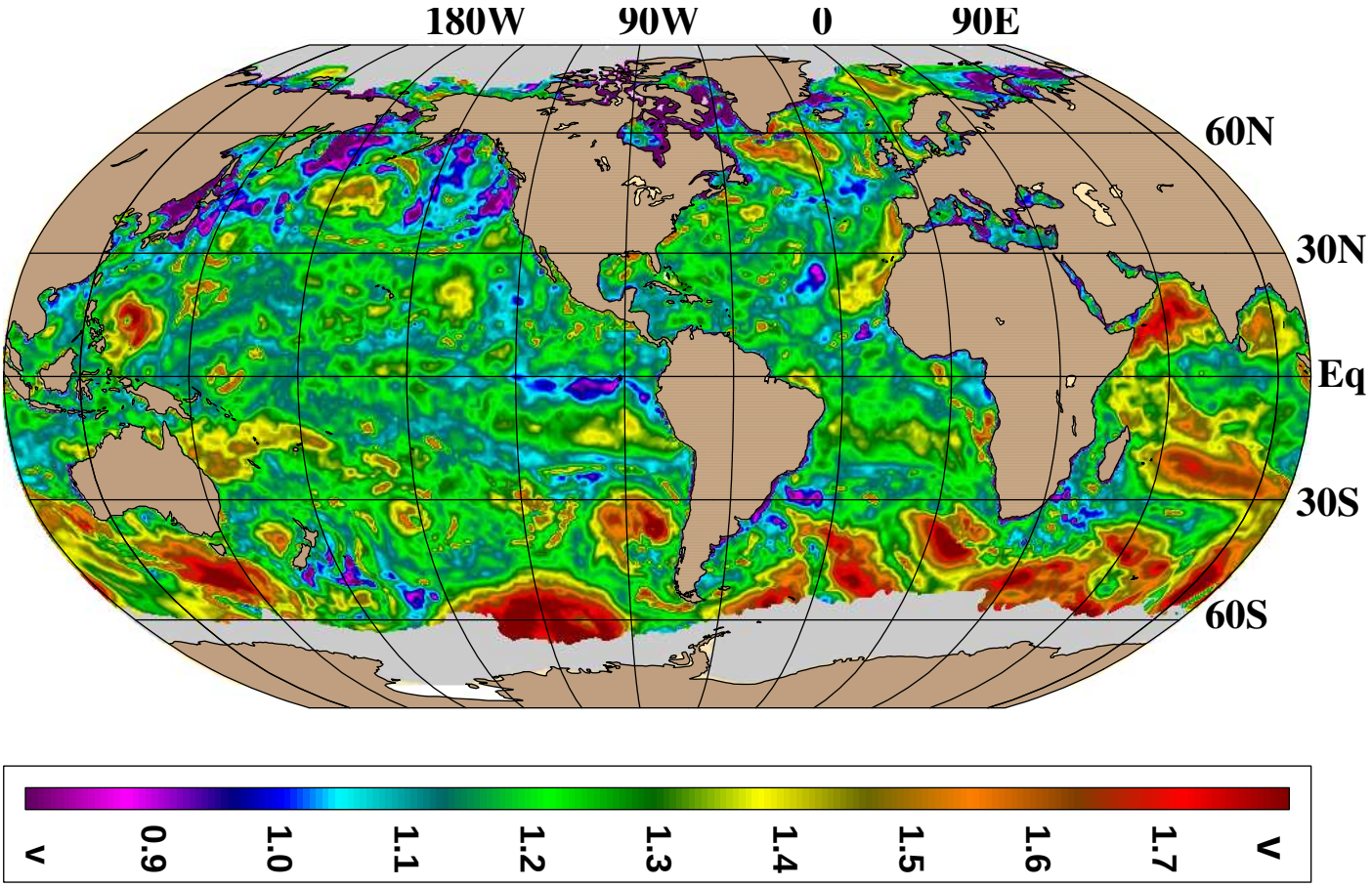
- C_D also depends on the sea state

  sea surface current speed

  ocean wave speed

Our focus is on the effects of sea state!

DRAG COEFFICIENT on 1 Aug 2005 (00Z)



- $C_D \times 10^3$ is
  - o based on polynomial equations (Kara et al. 2005),
  - o based on the COARE (v3.0) algorithm, and
  - o formulated using air–sea stability.

NOTE: Currents and wave speeds are NOT included in C_D.

METHODOLOGY

- **We would like vector averages of**

$$\vec{V} - V\vec{C} - V\vec{W}$$

- **Drop vector notation for simplicity**
  - **Wind speed at 10 m:** V
  - **Surface current speed:** VC
  - **Primary wave speed:** VW

- **Use zonal and meridional components for** V, VC **and** VW

GLOBAL DATA

- **Data sources:**
  - **V from 1° NOGAPS**
  - **VC from 1/12° HYCOM**
  - **VW from 1° WW3 model**

- **NOGAPS winds are used because**
  - **(1) its resolution is consistent with WW3, and**
  - **(2) it provides 3 hourly data (important for stability)**

Note: We apply 1° binning to VW for consistency.

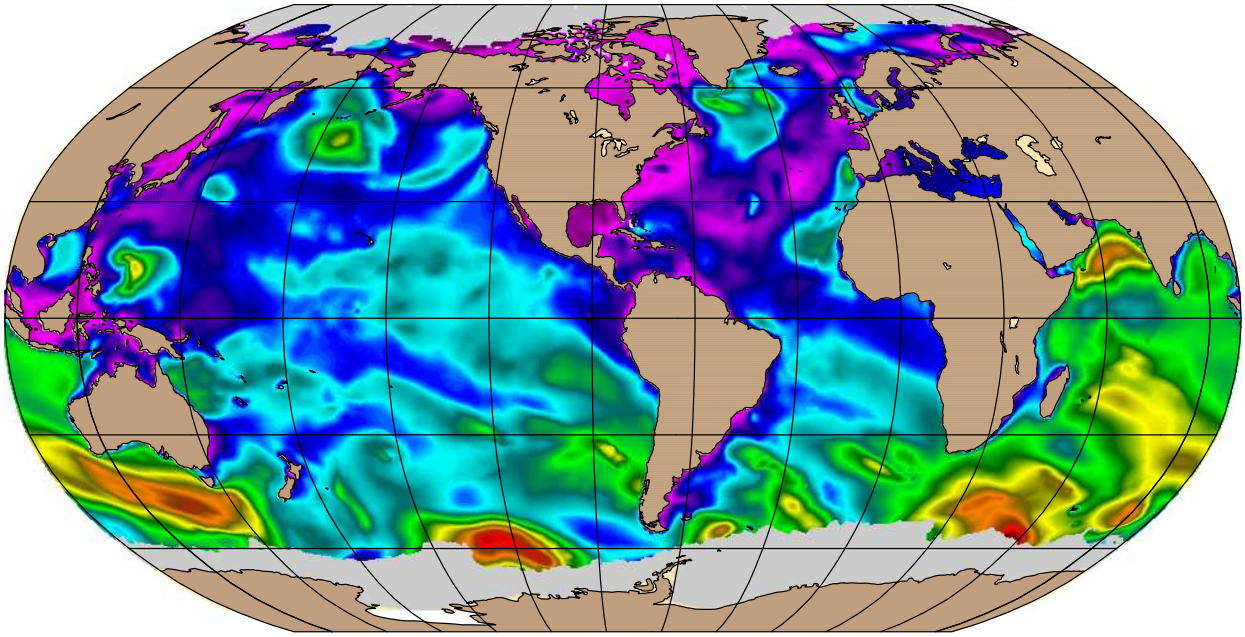
NOGAPS: Navy Operational Global Atmospheric Prediction System

HYCOM: HYbrid Coordinate Ocean Model

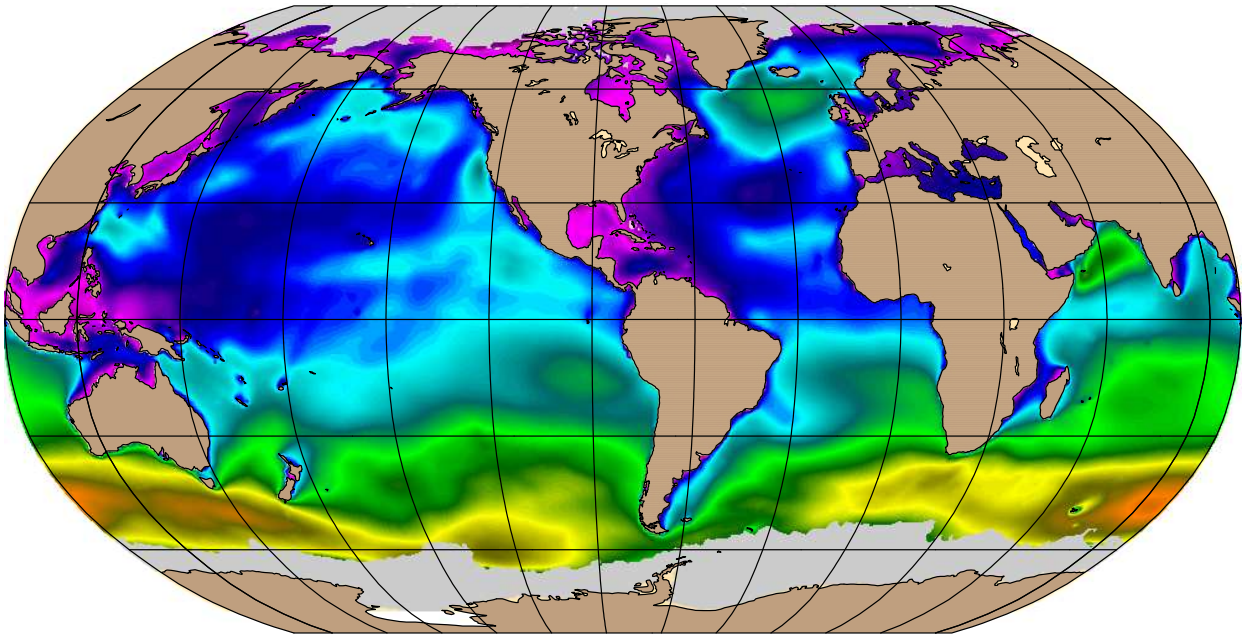
WW3: Wave Watch 3, a third generation wave model

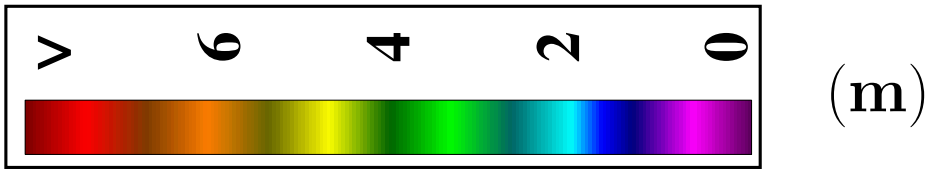
SIGNIFICANT WAVE HEIGHT FROM WW3

(a) 1 Aug 2005 (00Z)



(b) Aug 2005 Mean





These are needed for wave speed calculation.

CALCULATION OF WAVE SPEED

$$\mathrm{V} - \mathrm{VC} - \mathrm{VW}$$

- **V and VC are directly obtained (NOGAPS and HYCOM)**
- **However, VW has to be calculated (WW3)**

- **VW is calculated following Bourassa (2006)**

VW = $f\, V_{\mathrm{orb}}$

f **is constant (0.8), and**

V_{orb} **is the orbital velocity**

$$V_{\mathrm{orb}} = 3.14\, H/T$$

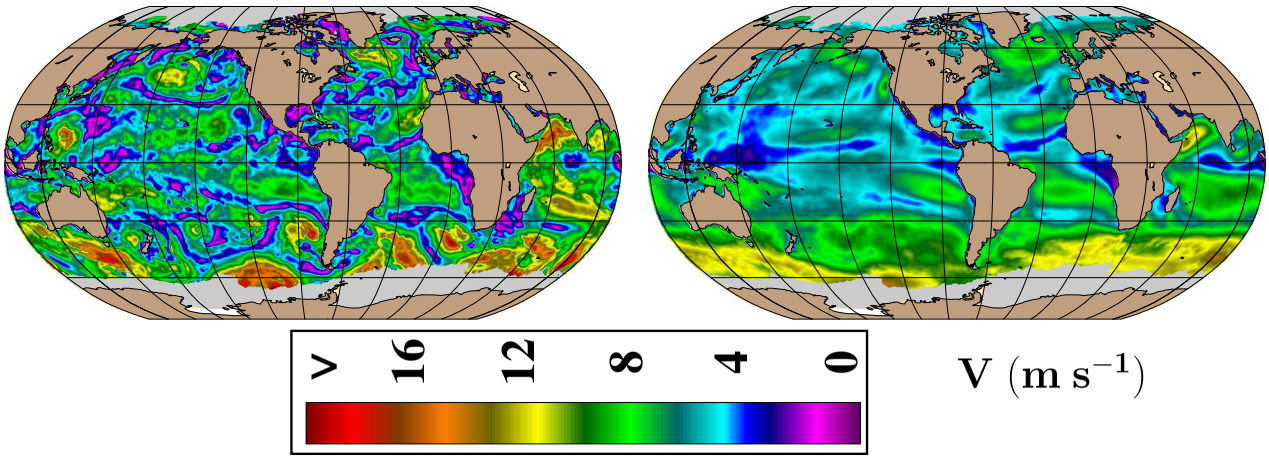
significant wave height (H**)**

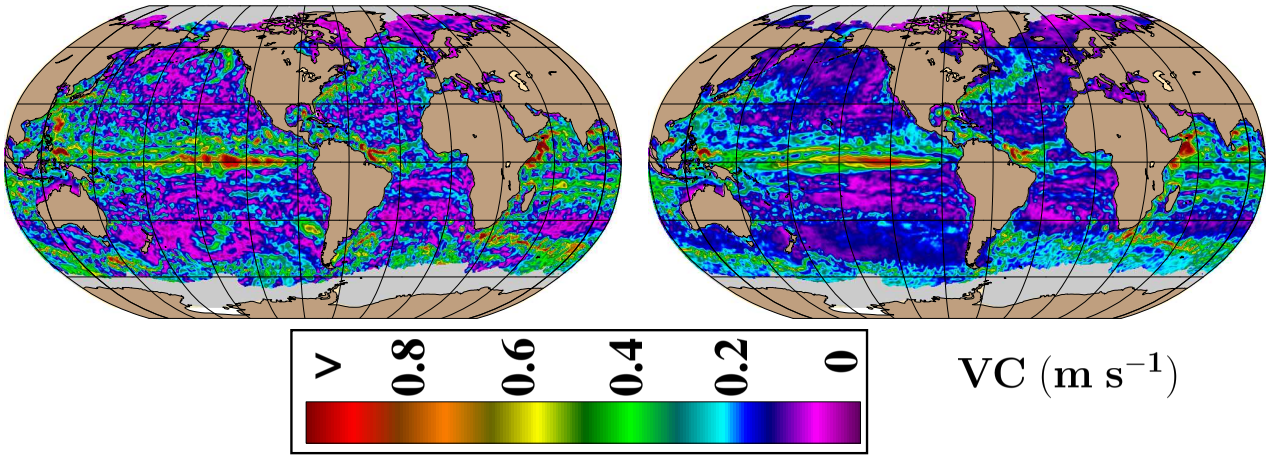
dominant wave period (T**)**

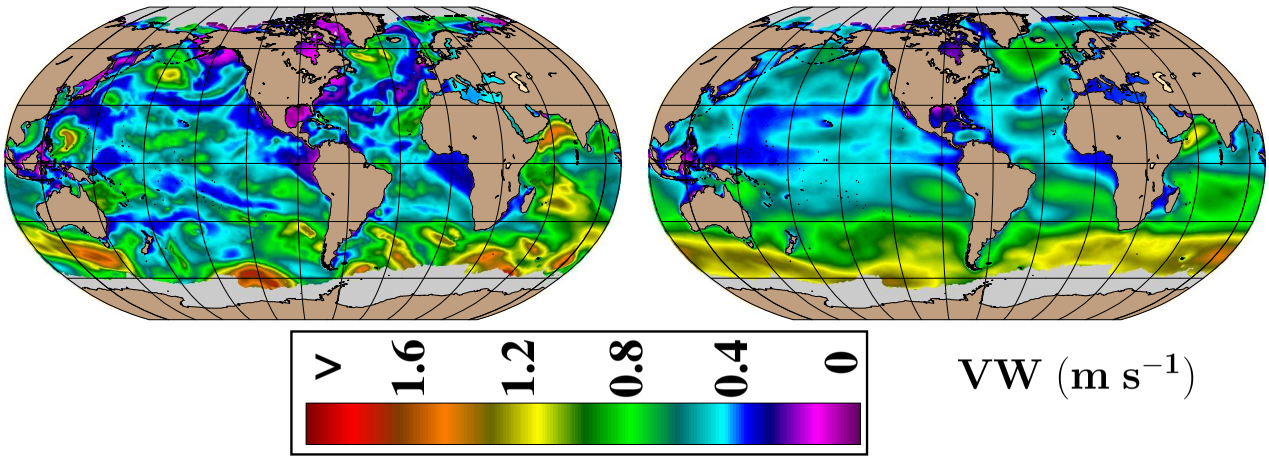
FIELDS USED FOR CALCULATIONS

(a) 1 Aug 2005 (00Z)

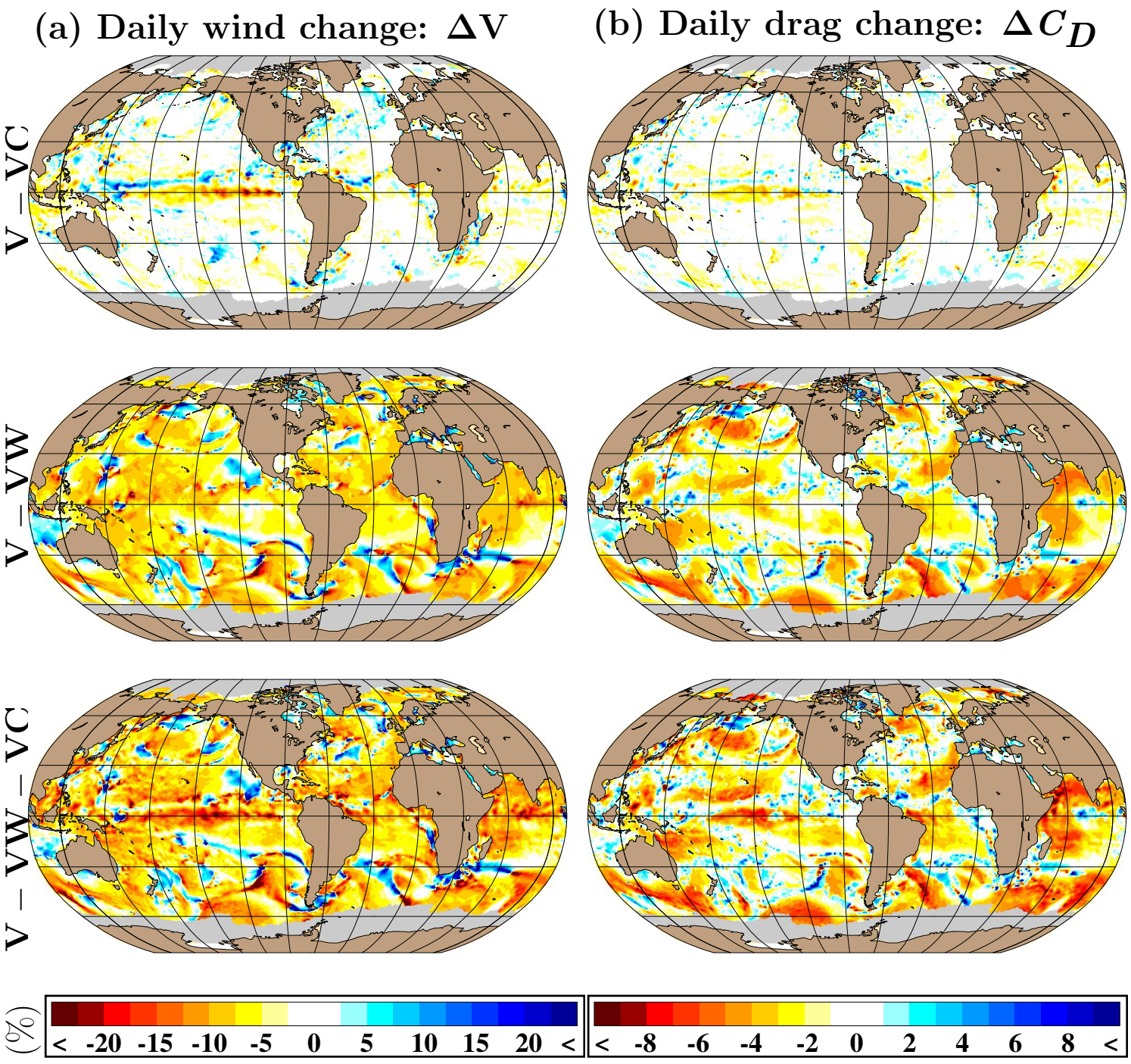
(b) Aug 2005 Mean





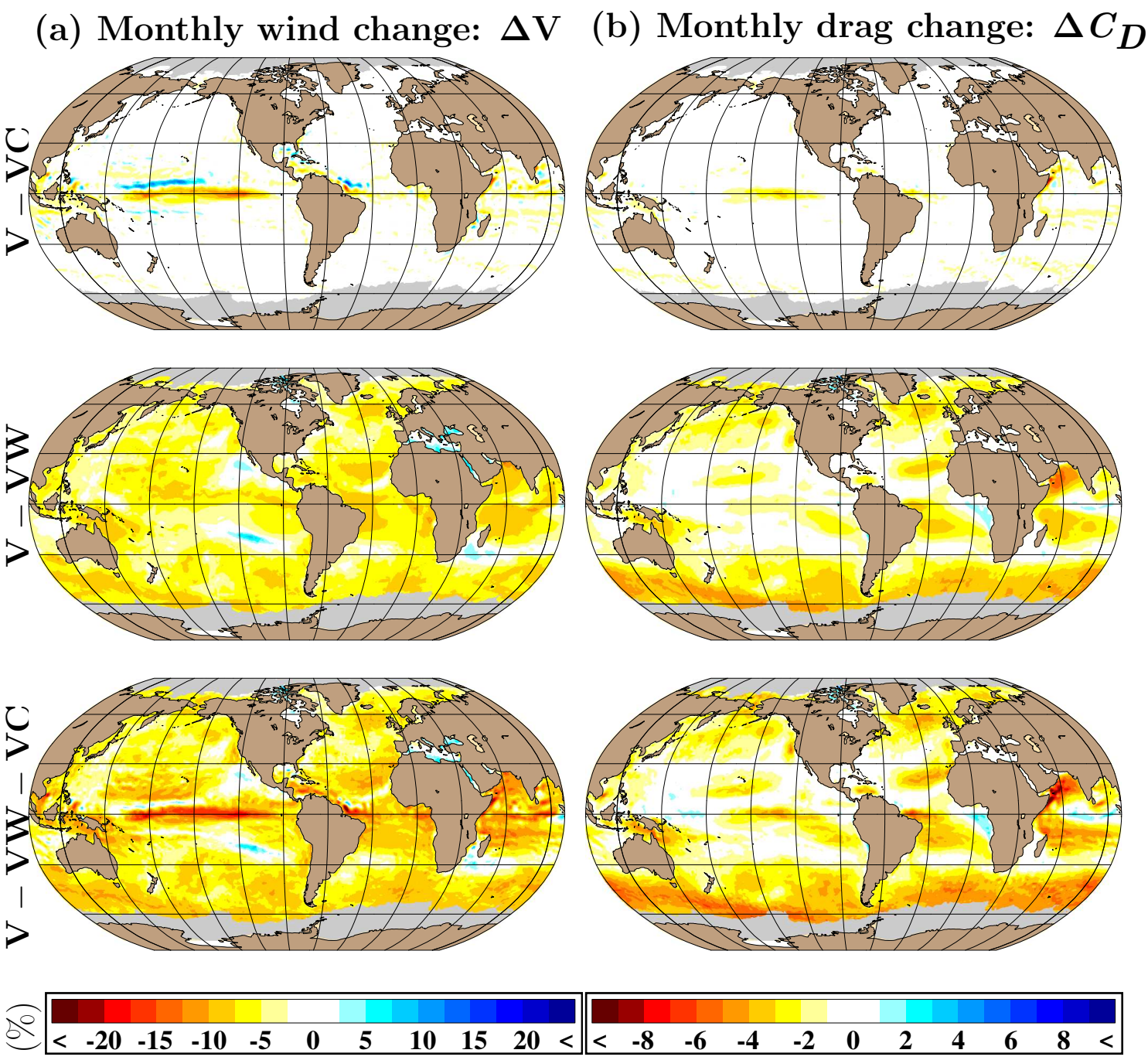


PERCENTAGE CHANGES (1 Aug 2005)



VC/VW/VC+VW reduces V by 1.0%/5.4%/6.4% globally
VC/VW/VC+VW reduces C_D by 0.3%/1.7%/1.9% globally

PERCENTAGE CHANGES (Aug 2005 mean)



VC/VW/VC+VW reduces V by 1.4%/5.5%/6.9% globally
VC/VW/VC+VW reduces C_D by 0.4%/1.7%/2.1% globally

CONCLUSION

- Spatial variability in C_D DOES exists
  - HYCOM already includes this variability
    - Wind speed, air–sea temp, relative humidity
- C_D should also include current and wave effects
  - Current speed: available at each model time step
  - Wave speed: what do we do about that?
    - a statistical relationship may be developed

- Globally, combined outcome of wind and wave speed:
  - Reduction in C_D by 2% only
  - However, one must note daily spatial variability
    - western boundary currents (current speed)
    - high latitudes (wave speed)